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Note

Effect of water depth on growth and survival of the stinging catfish *Heteropneustes fossilis* (Bloch, 1794) in pond rearing system of a humid subtropical agroclimatic region

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Abstract

The growth, survival and proximate composition of *Heteropneustes fossilis* (Bloch, 1794) were studied under different water depths (30, 60, 90 and 120 cm) for a period of 10 months, with a temperature range of 31.5 to 7.8°C [(May-June; 26.5-31.5°C; Stage 1); (July-September; 28.8-32.6°C; Stage 2); (October-November; 15.5-28.4°C; Stage 3); (December-February; 7.8-15.7°C; Stage 4)] under earthen pond conditions in the humid subtropical climate of Tripura State, India. All the ponds were of equal size (168 m^2; 14 m x 12 m) but with different water depths. The fishes were fed with a mixture of rice bran and mustard oil cake (1:1) @ 0.5-3% of their biomass. The growth, survival and proximate composition of fish were recorded in each stage. The average daily weight gain, feed conversion ratio, survival and proximate composition were found to be better in water depths of 60 and 90 cm during May to September when water temperature was ≥26.5°C. However, when water temperature was ≤21.4°C (October-February), growth and other attributes significantly reduced. Two-way ANOVA revealed that water depth and temperature, individually and interactively, affected the growth of *H. fossilis*. From this trial, it can be concluded that H. fossilis performs better when water depth is 60-90 cm and the ideal water temperature for the culture is 28.3-30.4°C. The study confirms the depth preference of *H. fossilis* under the humid subtropical condition and the information generated will help in the sustainable farming of this species.

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Fish segregates into different habitats in nature based on their physiological requirements, and this behaviour is known as 'habitat selection' (Neill and Bryan, 1991). Fish migrate to deeper waters or inshore/offshore when the water temperature exceeds or fall below their preference limits (Caulton, 1975). In tropical water bodies where water temperature fluctuates diurnally and seasonally, ponds should have sufficient depth to meet the temperature demand and other physiological needs of the fish. Despite the significant impact of water depth on fish growth and survival, limited information is available on this aspect. For carp culture, a depth of approximately one meter is recommended (Pillay, 1990), while for tilapia, 1.5 m during spawning and 2-2.5 m during rearing and wintering are advocated (Lin, 1991), but such information is greatly lacking for many other fishes.

Depth plays a crucial role in the farming of air-breathing fishes, particularly those that are obligatory air-breathers. If the water depth is too high, these fishes require to spend more energy on aerial respiration. Additionally, frequent migration to the water surface from the bottom can exhaust them, making them more vulnerable to surface predators

(Stoll *et al.*, 2008). On the other hand, if the depth is too low, the fishes may experience thermal shocks. Therefore, an attempt was made to assess the effect of water depths on growth, survival and proximate composition of an obligatory air-breathing catfish *Heteropneustes fossilis* (Bloch, 1794). This is a high-value catfish which is also known as 'stinging catfish' or '*Singhi*' (popularly) and it is endemic to oriental region (Talwar and Jhingran, 1991). However, due to overexploitation, pollution, habitat alteration and introduction of exotics, its availability in the wild has reduced (Vijaykumar, 1998). The captive breeding and seed production techniques of this fish are well standardised (Haniffa, 2004), but the information on grow-out production is lacking (Khan *et al.*, 2003; Puvaneswari *et al.*, 2009). No information is available on the effect of varying water depth on its growth performance. Therefore, the present study was attempted at the ICAR Research Complex for NEH Region (23°9065'N and 91°3135' E) Tripura Centre, Lembucherra, India.

The study was conducted under earthen pond conditions. Each pond had a size of 168 m^2 (14 m x12 m). The water depths assessed were 30, 60, 90 and 120 cm. The inlet and outlet facilities were maintained to ensure the desired water depths, consistently in the ponds. A sufficient number of fishes were stocked in a reservoir pond of 2000 m^2 for maintaining the stocking density in the experimental ponds at each level. Pond preparation and the basic management followed the method outlined by Debnath *et al.* (2015). The experimental fish were collected from the local markets and stocked @ 10000 nos. ha^{-1}. The fishes were fed a mixture of rice bran and mustard oil cake (1:1). The ten-month-long culture phase was categorised into four stages: Stage 1 (May-June) with a water temperature range of 26.5-31.5°C (average 28.3°C); Stage 2 (July-September) with a range of 28.8-32.6°C (average 30.4°C); Stage 3 (October-November) with a range of 15.5-28.4°C (average 18.3°C) and Stage 4 (December-February) with a range of 7.8-15.7°C (average 10.6°C). The feeding rate was set at 3, 2, 1 and 0.5% of fish biomass during stages 1, 2, 3 and 4, respectively. The water depths were periodically checked and adjusted as needed.

At the end of each stage, all fish were harvested and the survival rate was calculated. Ten fish were randomly sampled from each pond and weighed to estimate average daily gain (ADG), specific growth rate (SGR) and food conversion ratio (FCR) following the method described by De Silva (1989). Five fish were sacrificed to determine their proximate composition (AOAC, 1980). The stocking density was maintained at the same level for each stage by adding similar sized fishes from the reservoir tank. Water quality parameters were estimated at fortnightly intervals following standard methods (APHA, 2002).

The data were analysed using the SPSS version 21. One-way ANOVA and Duncan's Multiple range test (DMRT) were performed to determine the effect of water depth on the growth and survival of fish. Additionally, two-way ANOVA was conducted to assess the interactive effect of water depth and average temperature on growth, survival and proximate composition of fish.

The water quality parameters observed at different water depths during the experimental period are presented in Table 1. There was no significant differences in any of the water quality parameters, including the plankton density. The maximum water temperature was recorded in June, while the minimum was recorded in December (Debnath *et al.*, 2015). The slight increase in water temperature, pH and ammonia with the increase of water depth from 30 to 120 cm could be attributed to the increased organic matter load in the pond (Ali *et al.*, 2013). The levels of dissolved

Table 1. Water quality parameters in the experimental ponds at different water depths. Values having same superscripts in same row are not significantly different ($p \geq 0.05$)

Parameters	Depths			
	30 cm	60 cm	90 cm	120 cm
Temperature (°C)	26.22±0.14^a (7.8-32.6)	26.45±0.12^a (7.8-32.6)	26.54±0.15^a (8.2-32.5)	26.88±0.16^a (8.5-32.6)
Dissolved oxygen (ppm)	5.27±0.12^a (3.4-8.4)	5.22±0.11^a (3.5-8.6)	5.18±0.12^a (3.2-8.6)	5.17±0.12^a (3.2-8.4)
Transparency (cm)	33.42±1.12^a (23.5-55.4)	32.46±1.21^a (23.6-58.5)	32.14±1.24^a (23.4-58.4)	32.15±1.18^a (22.4-56.6)
Total alkalinity (ppm)	44.62±2.55^a (32.5-65.2)	45.75±2.17^a (33.5-66.4)	47.53±2.67^a (32.4-66.2)	48.43±2.52^a (32.1-68.6)
pH	7.35±0.11^a (5.5-8.6)	7.42±0.10^a (5.4-8.5)	7.47±0.16^a (5.2-8.4)	7.55±0.15^a (5.4-8.5)
Ammonia-N	0.38±0.04^a (0.15-0.50)	0.41±0.03^a (0.16-0.52)	0.44±0.07^a (0.18-0.54)	0.46±0.08^a (0.25-0.62)
Plankton (ml per 50-l)	2.72±0.55^a (0.5-5.8)	2.86±0.34^a (0.6-6.2)	3.07±0.22^a (0.8-6.5)	3.23±0.12^a (0.8-6.8)

oxygen, transparency and plankton indicated optimal pond conditions for fish growth (Diana and Lin, 1998).

The fish growth attributes under different water depths and temperatures are presented in Table 2 and their mean values are presented in Table 3. *H. fossilis* followed a sigmoid growth pattern across the different water depths and it was consistent across all the water depths evaluated in this study (Fig. 1). A similar growth pattern has been reported in the pond farming of Indian butter catfish *Ompok bimacultus* (Debnath *et al.*, 2015).

The interaction between water depth and temperature on fish growth attributes (Table 4), indicated that both water depth and temperature have significant individual and interactive effect on the average daily gain, survival and feed conversion

Table 2. Growth attributes of *H. fossilis* cultured in ponds with different water depths. Values in same column with same superscripts, for each stage, are not significantly different ($p \geq 0.05$)

Culture stage	Depth (cm)	Initial weight (g)	Final weight (g)	ADG (g day^{-1})	SGR (% day^{-1})	FCR	Survival (%)
Stage 1	30	4.85±0.27	15.41±0.84^{a}	0.17±0.01^{a}	1.95±0.07^{b}	3.46±0.06^{a}	64.30±3.00^{c}
	60	4.85±0.27	15.65±0.57^{a}	0.21±0.01^{b}	2.18±0.09^{a}	2.40±0.11^{b}	91.89±1.26^{a}
	90	4.85±0.27	15.76±0.62^{a}	0.22±0.01^{b}	2.20±0.09^{a}	2.36±0.21^{b}	86.34±2.55^{ab}
	120	4.85±0.27	15.59±0.60^{a}	0.18±0.01^{a}	1.91±0.07^{b}	3.69±0.10^{b}	80.11±1.45^{b}
Stage 2	30	15.41±0.84^{a}	40.60±1.97^{a}	0.24±0.01^{bc}	0.97±0.03^{a}	3.9±0.25^{b}	61.05±3.20^{c}
	60	15.65±0.57^{a}	39.56±1.63^{a}	0.24±0.00^{bc}	0.87±0.01^{b}	2.53±0.13^{a}	85.29±1.71^{a}
	90	15.76±0.62^{a}	44.74±1.84^{a}	0.27±0.01^{b}	0.93±0.04^{a}	2.63±0.23^{a}	80.69±3.32^{a}
	120	15.59±0.60^{a}	43.25±1.71^{a}	0.19±0.01^{c}	0.85±0.04^{b}	3.76±0.04^{b}	71.63±2.52^{b}
Stage 3	30	40.60±1.97^{a}	61.73±2.30^{b}	0.19±0.01^{c}	0.44±0.03^{a}	3.66±0.06^{a}	36.44±0.55^{c}
	60	39.56±1.63^{a}	63.42±2.38^{ab}	0.39±0.03^{a}	0.79±0.05^{b}	2.8±0^{b}	73.94±1.54^{a}
	90	44.74±1.84^{a}	68.52±1.94^{a}	0.38±0.03^{a}	0.70±0.06^{b}	3.5±0.17^{a}	70.2±4.10^{a}
	120	43.25±1.71^{a}	69.90±2.51^{a}	0.22±0.01^{b}	0.55±0.04^{c}	4±0.11^{c}	52.60±2.48^{b}
Stage 4	30	61.73±2.30^{b}	77.28±1.11^{b}	0.11±0.01^{b}	0.21±0.02^{a}	3.84±0.19^{a}	23.52±0.16^{c}
	60	63.42±2.38^{ab}	80.22±1.87^{b}	0.22±0.02^{a}	0.30±0.03^{b}	2.8±0.04^{b}	59.40±1.11^{a}
	90	68.52±1.94^{a}	91.58±2.18^{a}	0.23±0.02^{a}	0.30±0.03^{b}	3.1±0.05^{b}	60.52±2.47^{a}
	120	69.90±2.51^{a}	89.77±2.25^{a}	0.20±0.02^{a}	0.36±0.04^{c}	3.8±0^{a}	46.45±1.96^{b}

Table 3. Mean values of growth, survival and FCR of *H. fossilis* reared in ponds with different water depths. Values in same column with same superscripts are not significantly different ($p \geq 0.05$)

Water depth (cm)	Initial weight (g)	Final weight (g)	ADG (g day^{-1})	SGR (%day^{-1})	FCR	Survival (%)
30	4.85±0.27	77.28±1.11^{b}	0.26±0.01^{a}	1.01±0.09^{a}	3.72±0.08^{a}	46.33±5.21^{c}
60	4.85±0.27	80.22±1.87^{b}	0.30±0.02^{a}	1.08±0.09^{a}	2.63±0.06^{b}	77.63±3.76^{a}
90	4.85±0.27	91.58±2.18^{a}	0.32±0.02^{a}	1.08±0.09^{a}	2.90±0.15^{b}	74.44±3.28^{ab}
120	4.85±0.27	89.77±2.25^{a}	0.31±0.02^{a}	1.07±0.09^{a}	3.21±0.04^{a}	62.70±4.22^{b}

Table 4. Interactive effect of water depth and temperature on ADG, SGR, FCR and survival of *H. fossilis* ($^{**}p \leq 0.001$ and $^{***}p \leq 0.0001$)

Source of variation	Parameter	Temperature	Depth	Interaction	Residual	Total
Sum of squares	ADG	0.28	0.27	0.19	0.49	1.24
	SGR	70.73	0.64	0.85	4.43	76.67
	FCR	1.79	12.46	1.33	1.80	17.40
	Survival	6051.14	14609	2347.68	428.40	23436.36
df		3	3	9	144	159
Mean squares	ADG	0.09	0.09	0.02	0.003	
	SGR	23.57	0.21	0.09	0.03	
	FCR	0.59	4.15	0.14	0.05	
	Survival	2017.04	4869.71	260.85	13.38	
F value	ADG	27.99***	27.04***	6.34***		
	SGR	766.16***	7.02***	3.08**		
	FCR	10.57***	73.53***	2.62**		
	Survival	150.66***	363.75***	19.48***		

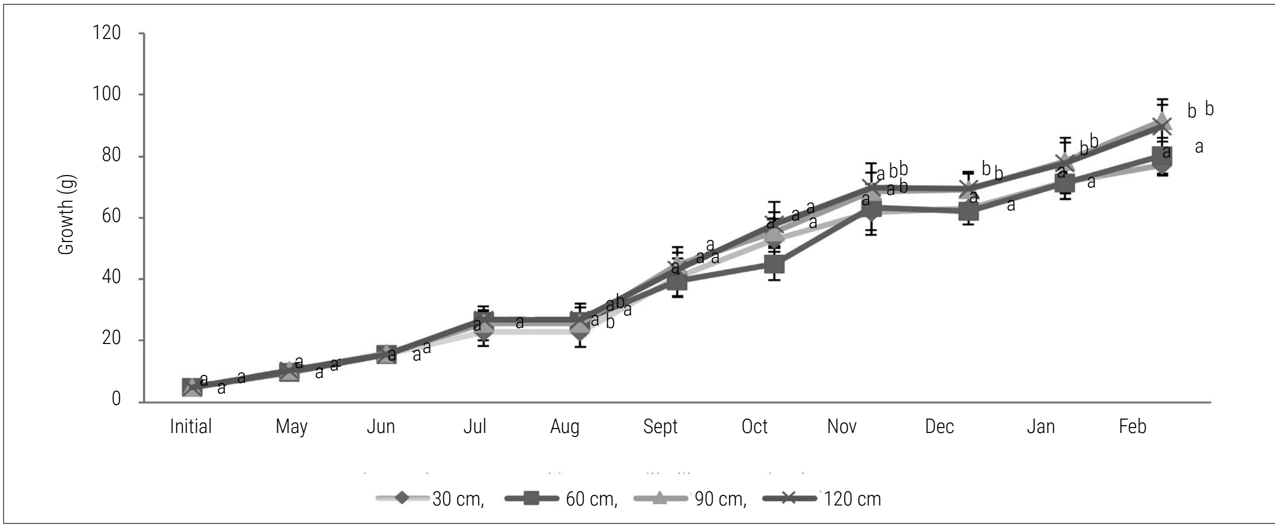

Fig. 1. Monthly growth of *H. fossilis* (in terms of weight) reared in ponds with different water depths. Lines having same superscripts in same month are not significantly different.

ratio of *H. fossilis*. Based on these results, it can be concluded that the water depth plays a crucial role in the growth and survival of *H. fossilis*. Similar results have been reported in the farming of tilapia from Egypt by El-Sayed *et al.* (1996).

The growth rate of fish was found to vary with changes in water temperature. The SGR was highest in May-June, followed by July-September, indicating that the water temperature and associated factors such as dissolved oxygen, pH, alkalinity and plankton density were more favourable for *H. fossilis* during these periods. Vasal and Sundaraj (1978) also reported that *H. fossilis* grows better when water temperature ranges from 31.3 to 32°C, while growth rate decreases when the water temperature is between 15.5 and 21.4°C. High mortality (Fig. 2) was recorded in stage 4, particularly at a water depth of 30 cm, where the average water temperature was 10.6°C (ranging from 7.8 to 13.7°C) indicating cold stress. Fungal infections were observed in some fishes in the ponds with a depth of 30 cm. Reduced growth and feeding activity in the 30 cm depth during stage 3 and 4 suggested that the fish might have allocated more energy in maintaining physiological functions rather than growth (Stickney, 1991). Vasal and Sundaraj (1978) also reported that the growth of *H. fossilis* was reduced when water temperature fell below 25°C.

During stage 2, young fish were found at all depths (except 30 cm), indicating the natural breeding season of the fish and favourable environmental factors. Smaller fishes were found to be more adaptable to temperature variations than the larger fishes as reported by Neill and Bryan (1991) and El-Sayd *et al.* (1996). Maximum mortality was recorded at a depth of 30 cm, as the fish experienced severe thermal shock during winter and summer seasons (Neill and Bryan,

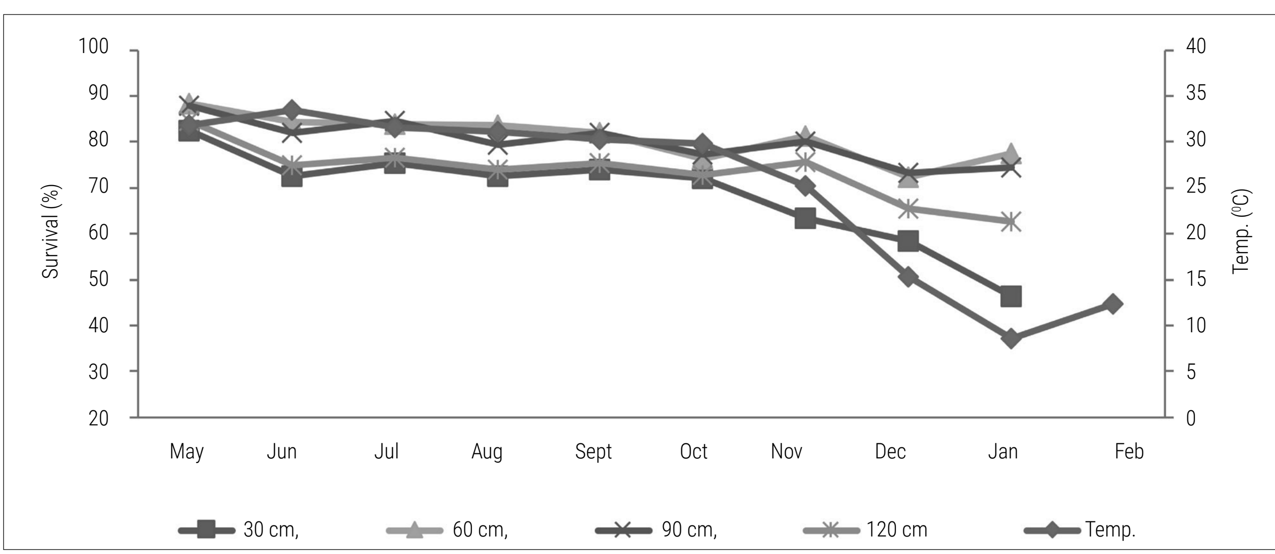

Fig. 2. Monthly survival (%) of *H. fossilis* reared in ponds with different water depths and temperatures

1991). Low growth and survival at a depth of 120 cm could be attributed to the increased expenditure of energy for frequent migration to water surface for aerial respiration, as *H. fossilis* is an obligatory air breathing fish (Armbruster, 1998). Overall, better fish growth and survival were recorded at water depths of 60 and 90 cm.

The proximate composition of *H. fossilis* under different depths and temperature is presented in Table 5 and their interactions are shown in Table 6. Both water depth and temperature, individually and interactively, had an impact on the protein, lipid and ash content of the fish. Better growth and body composition were observed in fish reared at 60 and 90 cm depth during stage 1 and 2. However, in stage 3 and 4, the protein and lipid contents were significantly reduced at depths of 30 and 120 cm. This could be attributed to the stress experienced by the fish due to low water temperature and extreme water depths, which increased their metabolic rate (Caulton, 1982). Similar results have also been reported in African catfish (Usmani and Jafri, 2002), tilapia (El-Sayd *et al.*,1996) and carps (Ali *et al.*, 2006). Furthermore, a detailed study on length-weight relationship and condition factor of the fish reared under varying water depths is also recommended.

Finally, based on the findings, it can be concluded that the water depths play a crucial role for the culture of the obligatory air-breathing fish *H. fossilis.* For better growth

Table 5. Proximate composition of *H. fossilis* reared under different depths and temperatures. Values in the same column with same superscripts, for each stage, are not significantly different (p≥0.05)

Culture stages	Depth (cm)	Proximate composition (%)		
		Protein	**Lipid**	**Ash**
Stage 1	30	11.60±0.53^{a}	1.46±0.11^{a}	2.40±0.20^{a}
	60	14.33±0.11^{c}	2.86±0.30^{b}	2.60±0.20^{a}
	90	14.36±0.15^{c}	3.00±0.34^{b}	2.60±0.53^{a}
	120	12.53±0.57^{b}	1.73±0.11^{a}	2.33±0.11^{a}
Stage 2	30	12.40±0.20a	1.86±0.11a	2.20±0.20a
	60	16.40±0.20b	3.40±0.20b	3.46±0.30b
	90	16.46±0.30b	3.46±0.30b	3.42±0.11b
	120	12.63±0.51a	2.13±0.11a	2.40±0.20a
Stage 3	30	12.40±0.20a	1.66±0.11a	2.13±0.11a
	60	15.66±0.11b	2.66±0.11b	2.80±0.34b
	90	15.73±0.41b	2.56±0.23b	2.86±0.50b
	120	12.26±0.11a	1.64±0.12a	2.06±0.11a
Stage 4	30	10.60±0.53a	1.40±0.20a	1.66±0.11a
	60	14.40±0.20b	2.33±0.11b	2.13±0.12b
	90	14.44±0.22b	2.13±0.12b	2.26±0.23b
	120	11.05±0.41a	1.40±0.20a	1.82±0.20a

Table 6. Interactive effect of water depth and temperature on proximate composition of *H. fossilis* reared under different water depths (*p≤0.05, **p≤0.001, *** p≤0.0001)

Source of variation	Parameters	Temperature	Depth	Interaction
Sums of squares	Protein	24.69	130.21	5.36
	Lipid	4.95	15.97	0.91
	Ash	5.07	5.10	1.54
df		3	3	9
Mean squares	Protein	8.23	43.40	0.59
	Lipid	1.65	5.32	0.10
	Ash	1.69	1.70	0.17
F value	Protein	70.80***	373.38***	5.13**
	Lipid	44.0***	142.01***	2.69***
	Ash	25.05***	251.8***	2.54*

and survival, it is recommended to maintain water depths within the range of 60 to 90 cm even during winter months. Additionally, the ideal water temperature for maximising growth of the fish is 28.3-30.4°C which typically occurs during May-September in the subtropical climatic conditions of the region.

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